Energy Research Institute

UNIVERSITY OF LEEDS

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The influence of obstacle separation distance on explosion severity. Is our design database conservative enough?

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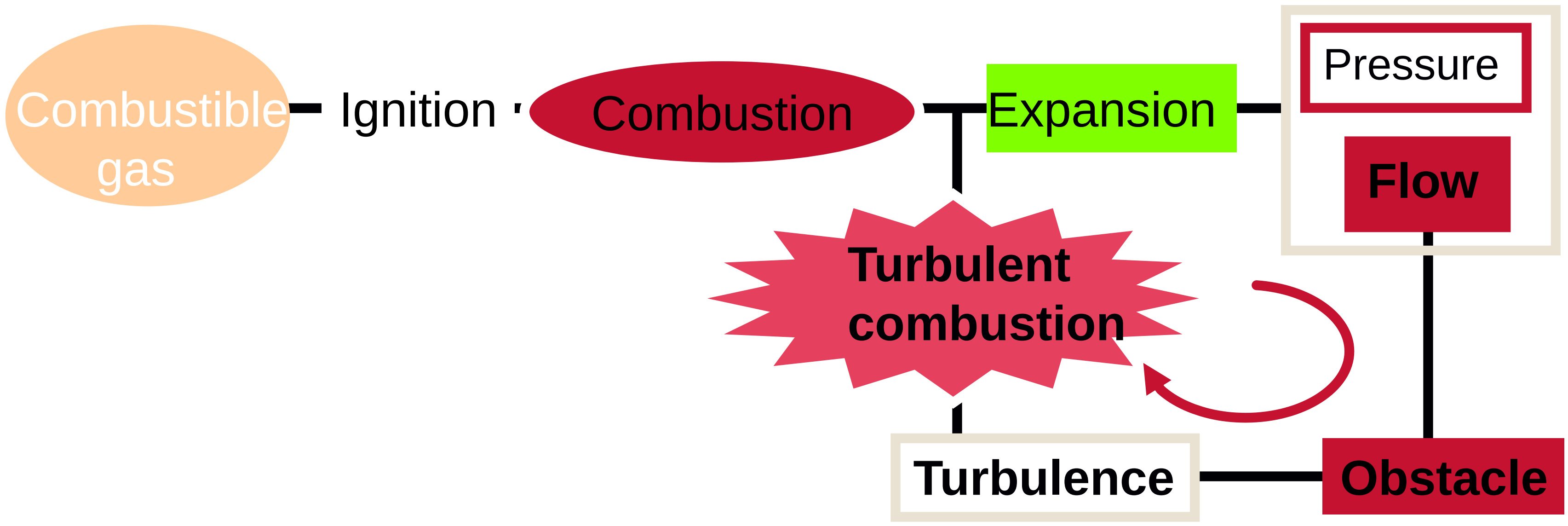
Turbulent explosion enhancement as a gas dynamic feed-back loop



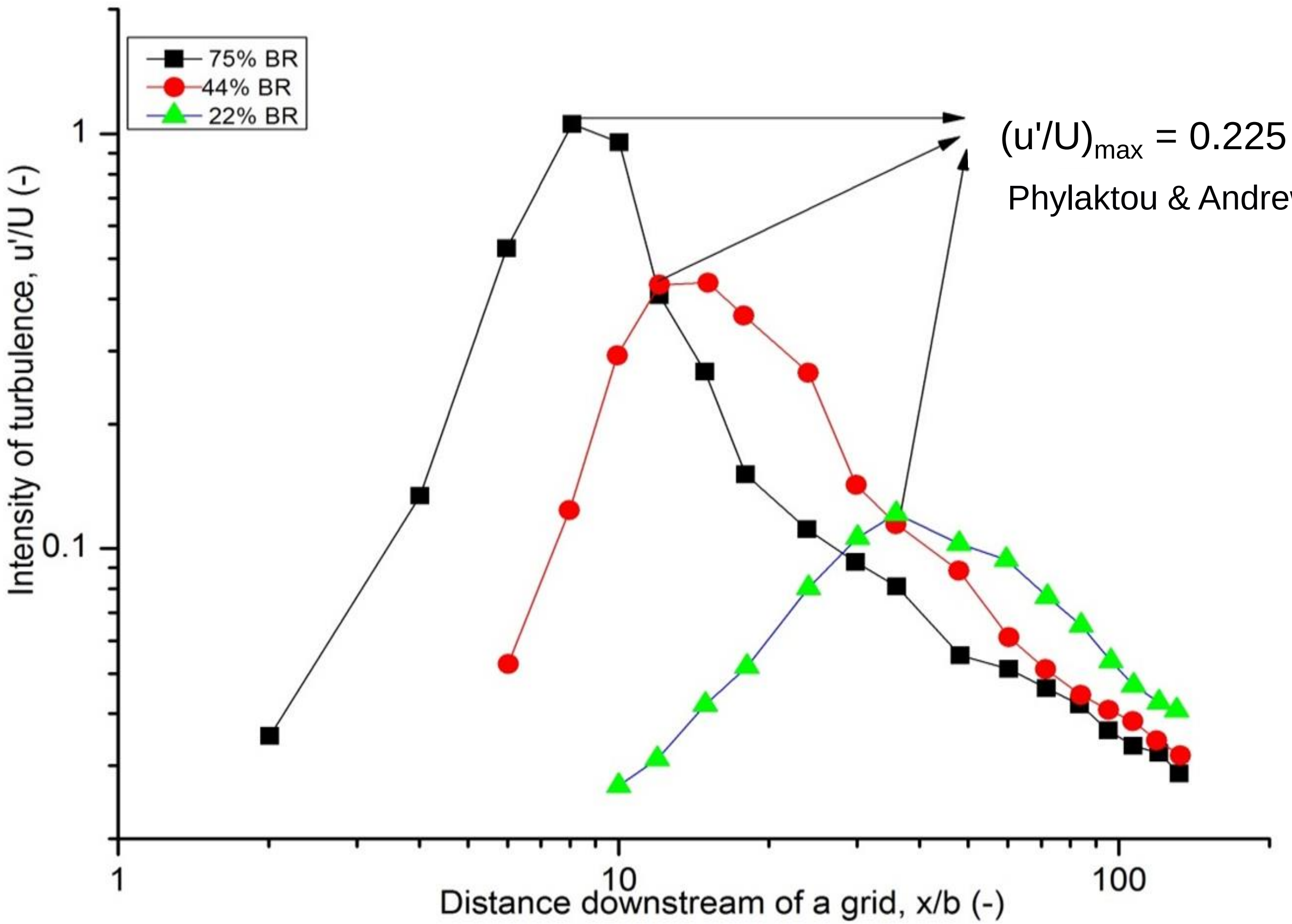
Much work has been done with multi- obstacles investigating this mechanism to understand

- increased explosion severity in congested areas
- transition to detonation

Limited work on the effect of **obstacle separation distance**

Cold flow turbulence

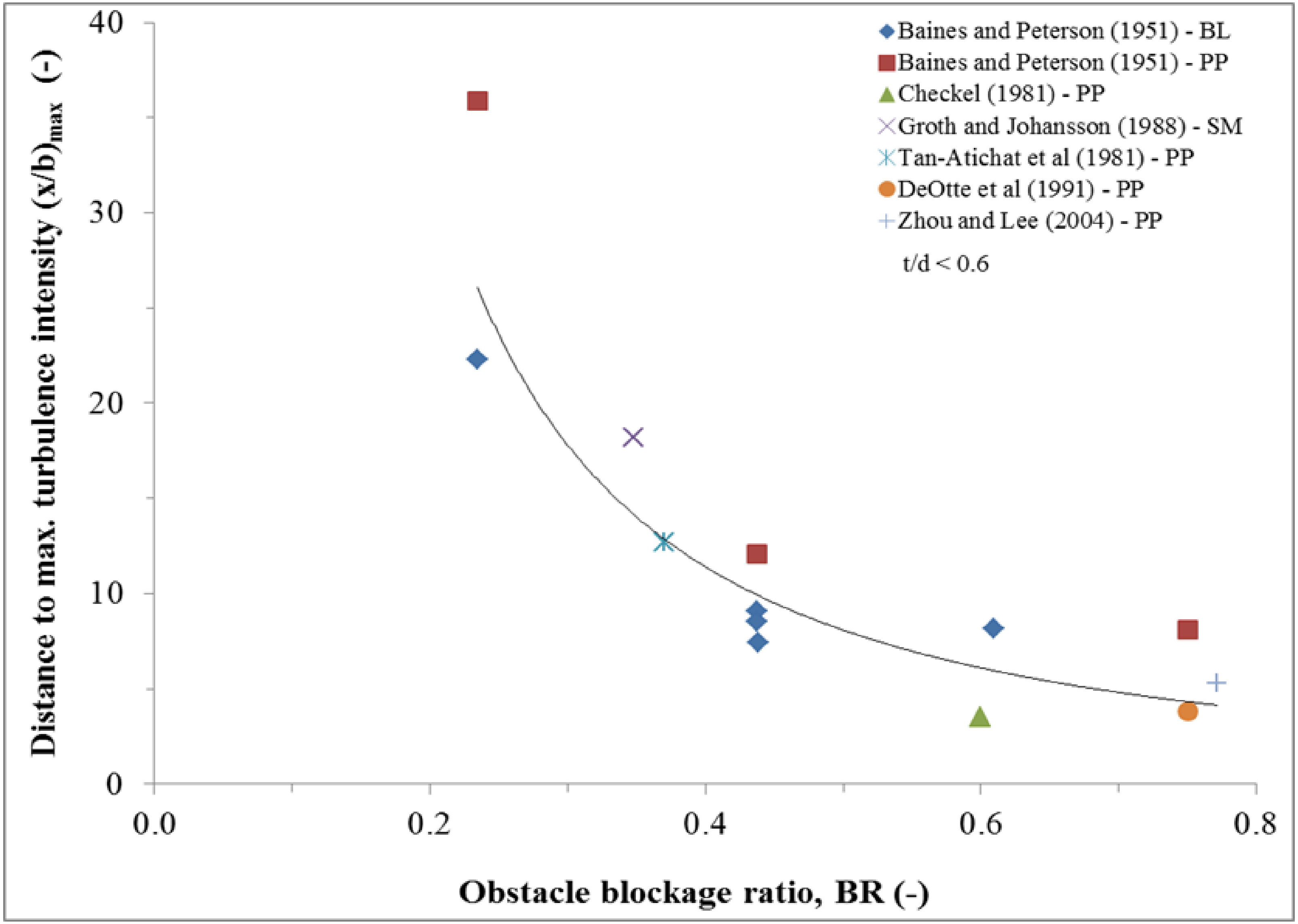
Baines and Peterson (1951)



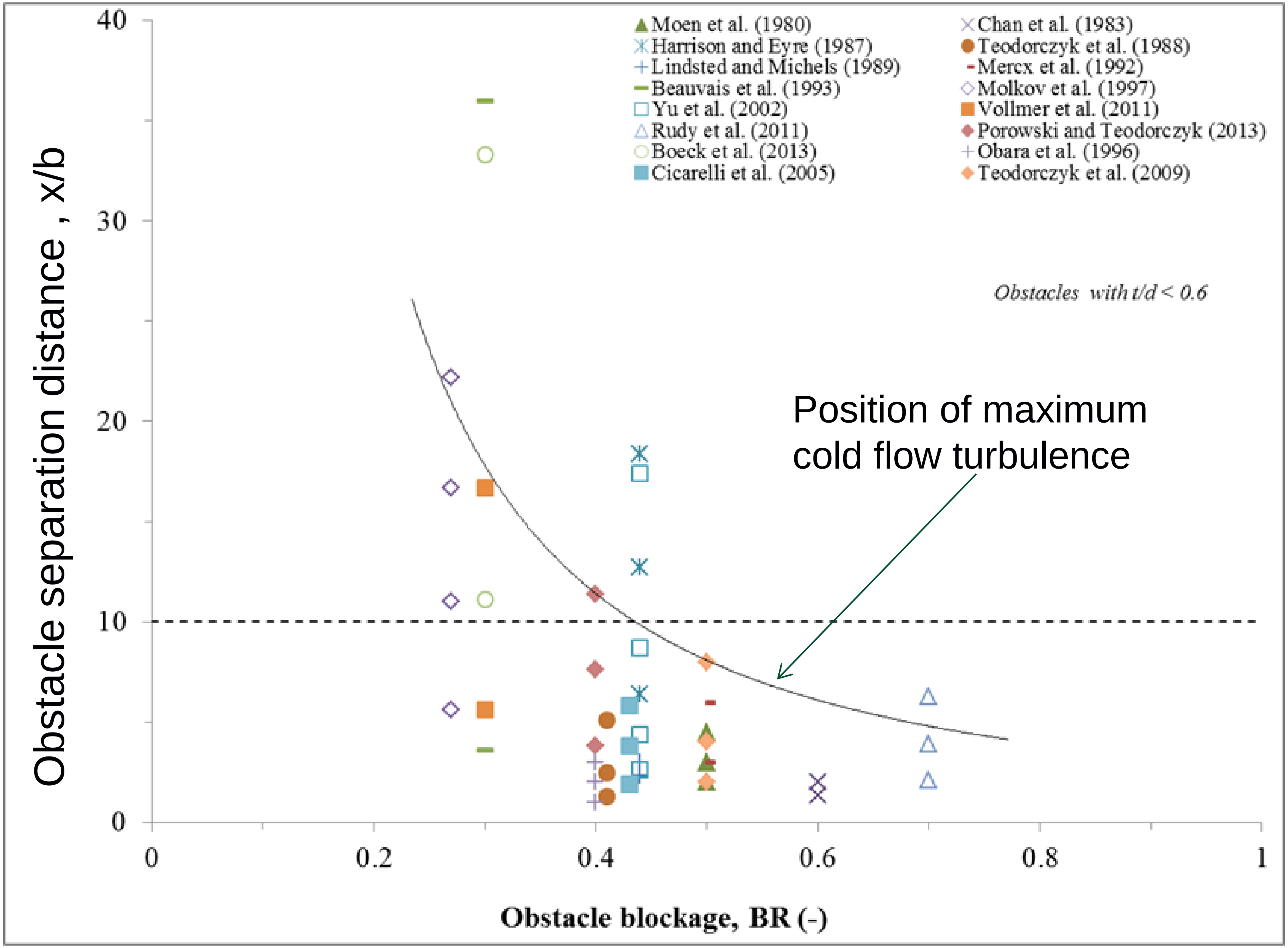
$(u'/U)_{max} = 0.225\ K^{0.5}$

Phylaktou & Andrews (1994)

Position of maximum cold flow turbulence



Explosion & Detonation studies with variable obstacle spacing

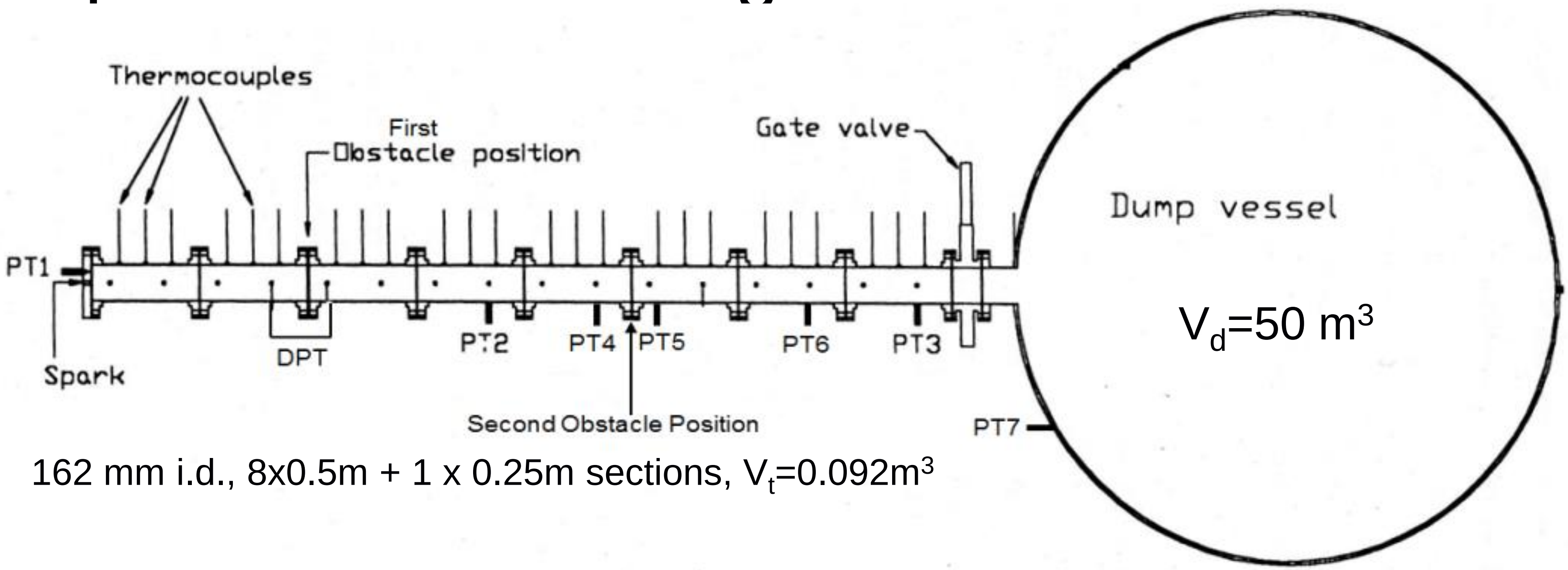


Objectives

To systematically vary the obstacle separation distance in gas explosions in order to

- identify the worst case interaction distance and
- relate this to the cold flow turbulence generation and decay profile.
- Relate findings to other explosion studies and explosion safety

Experimental – test rig



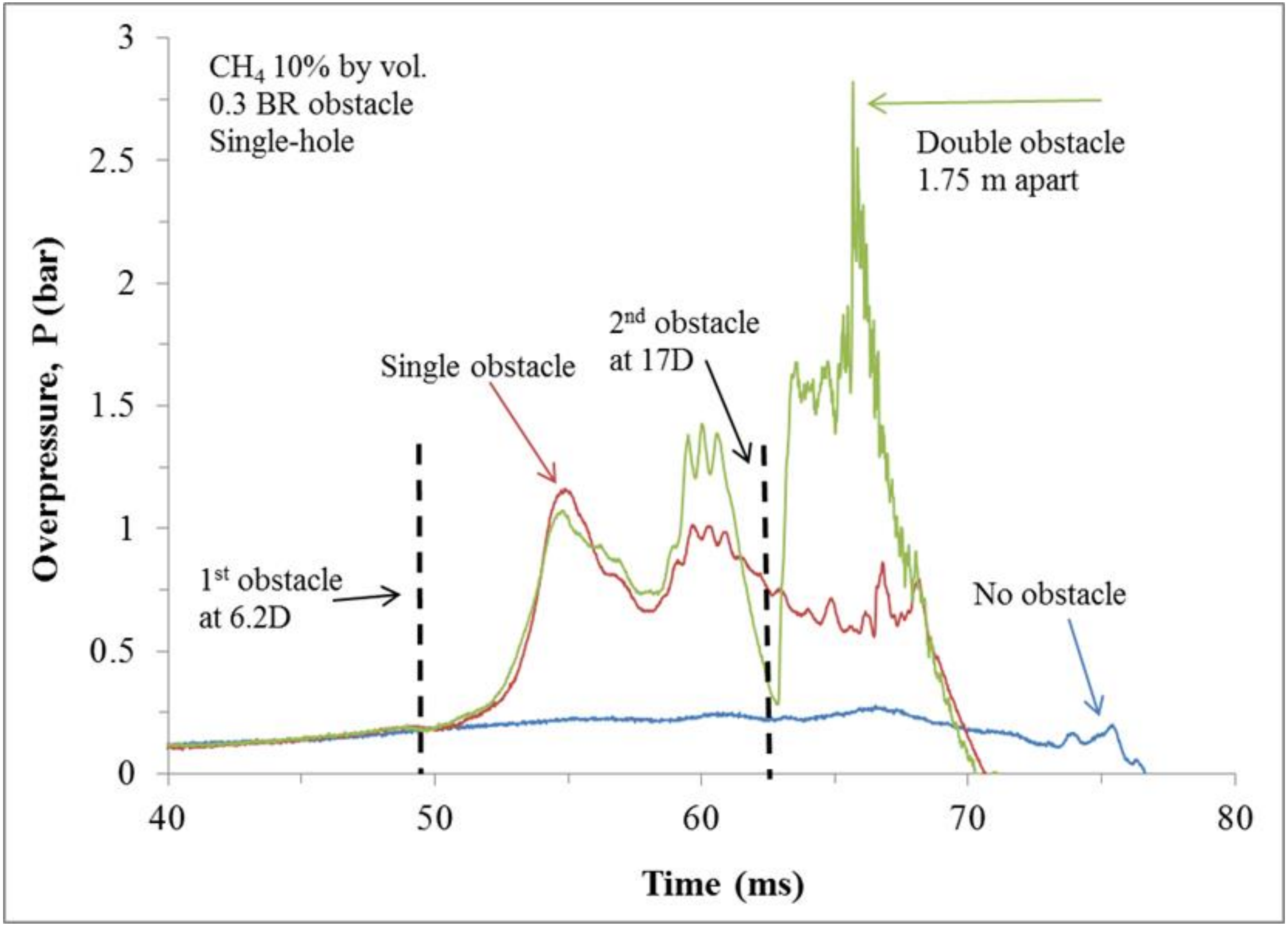
162 mm i.d., 8x0.5m + 1 x 0.25m sections, V_t=0.092m^3

Experimental – obstacles

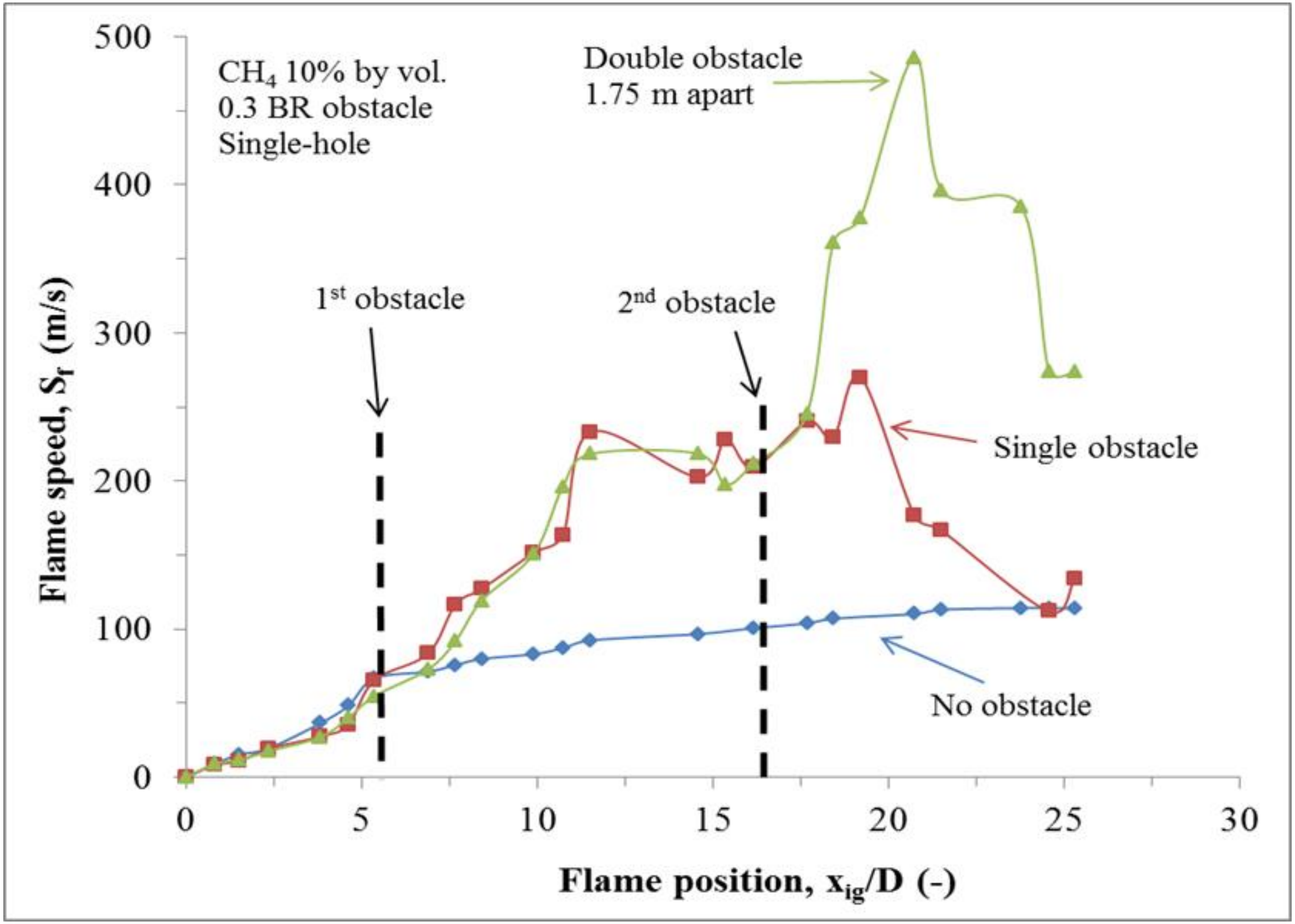
Hole grid plates

Flat bars

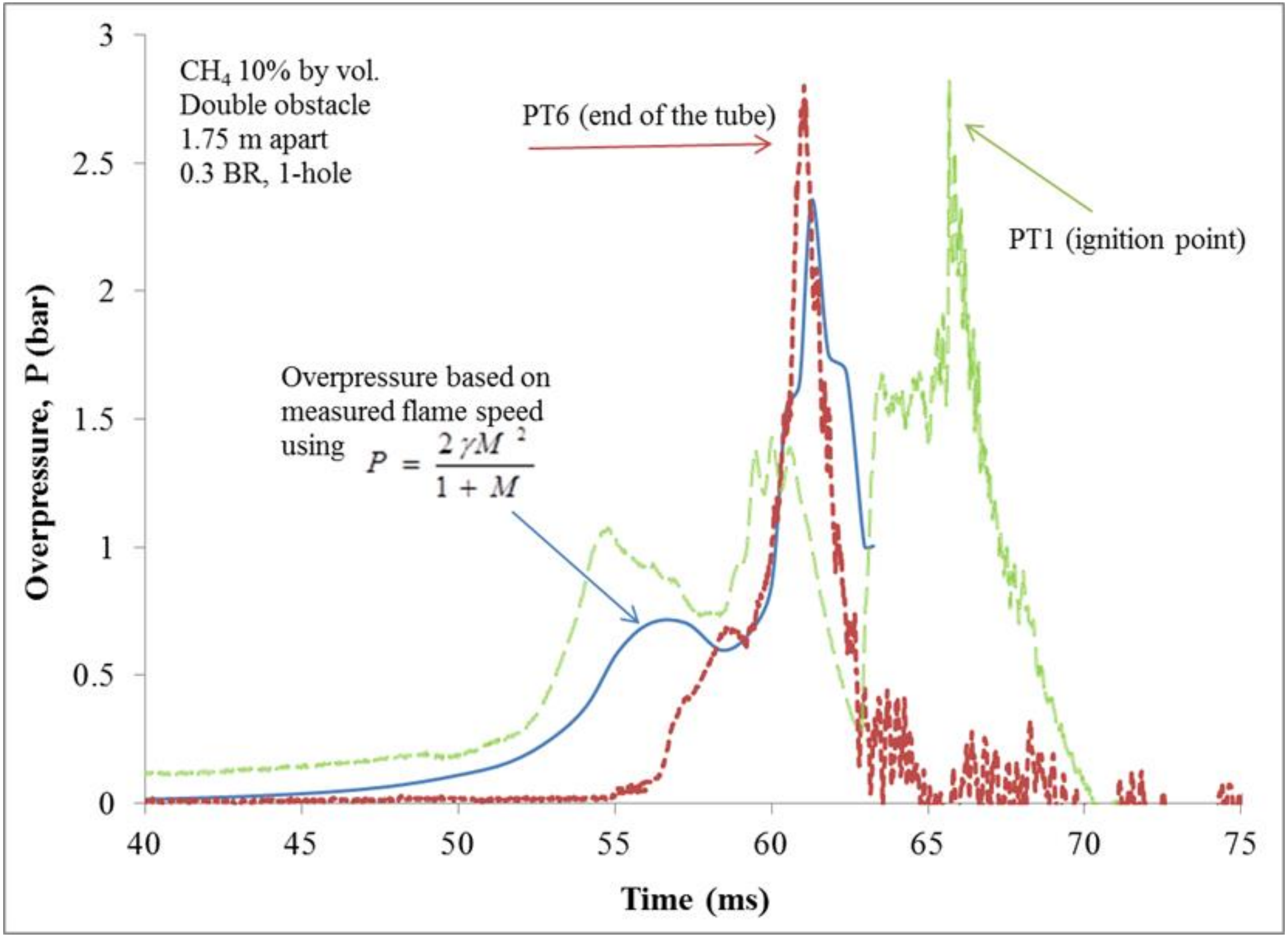
Results – General - Pressure



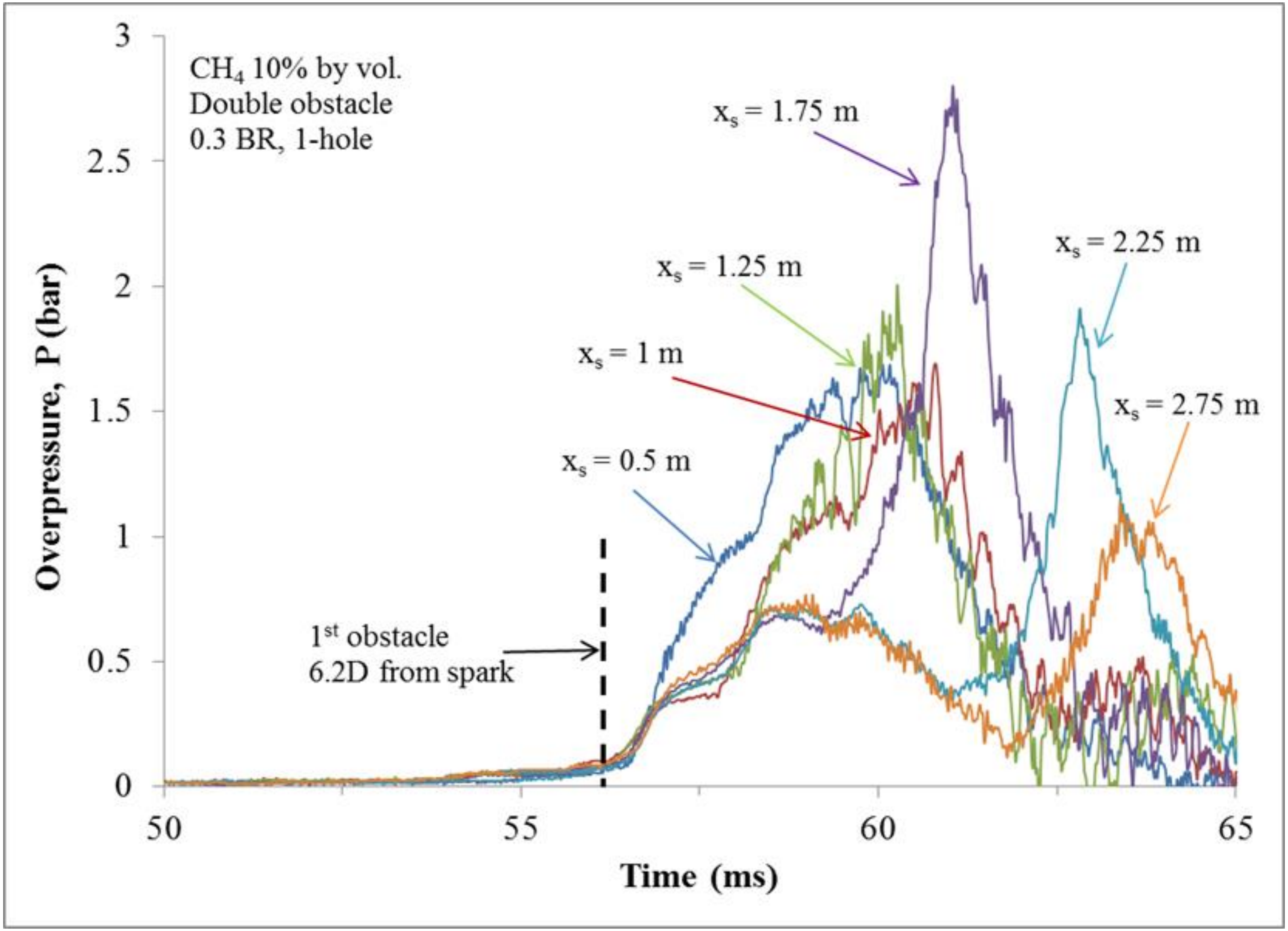
Results – General – Flame speed



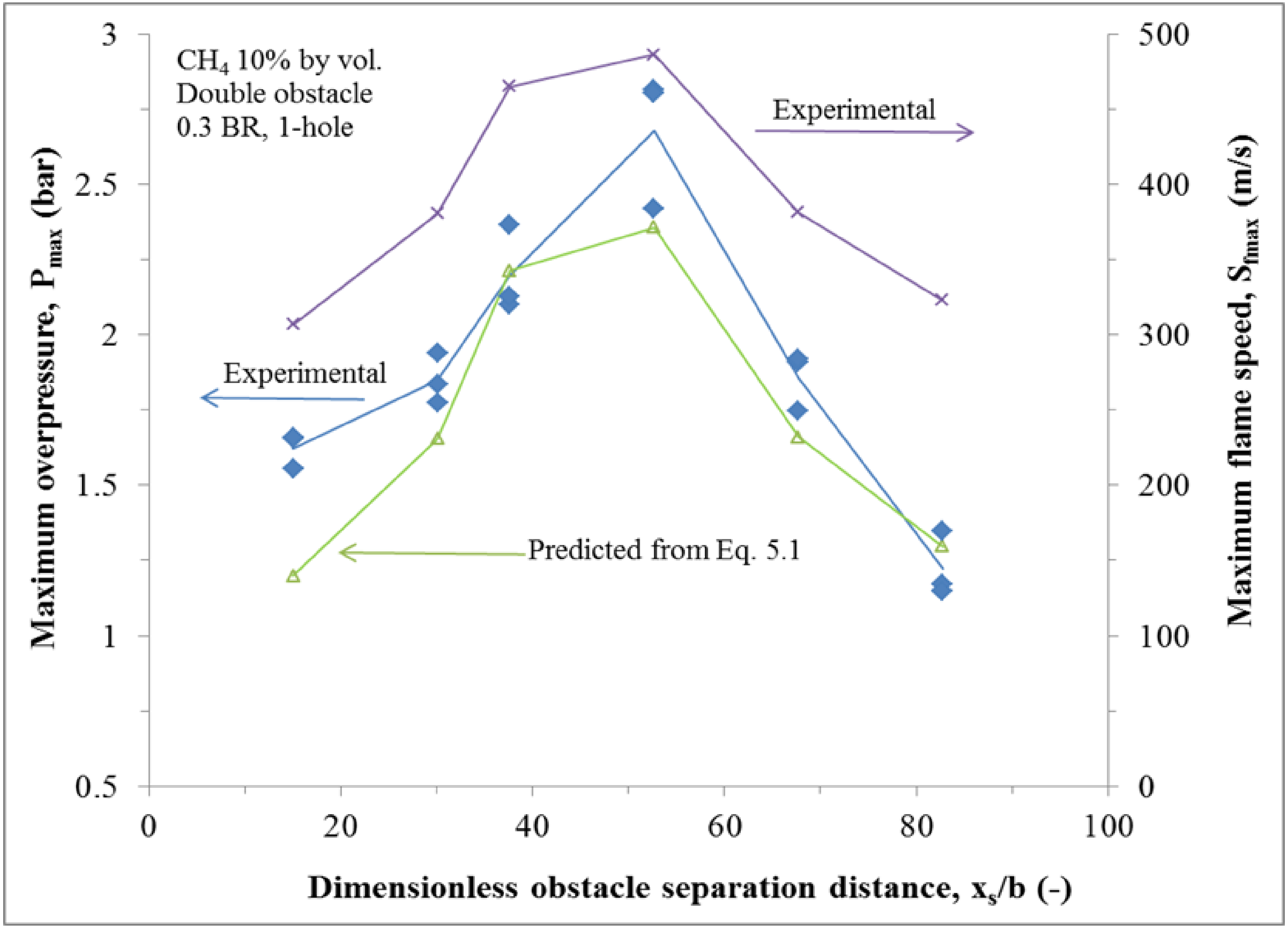
Flame speed generated pressure



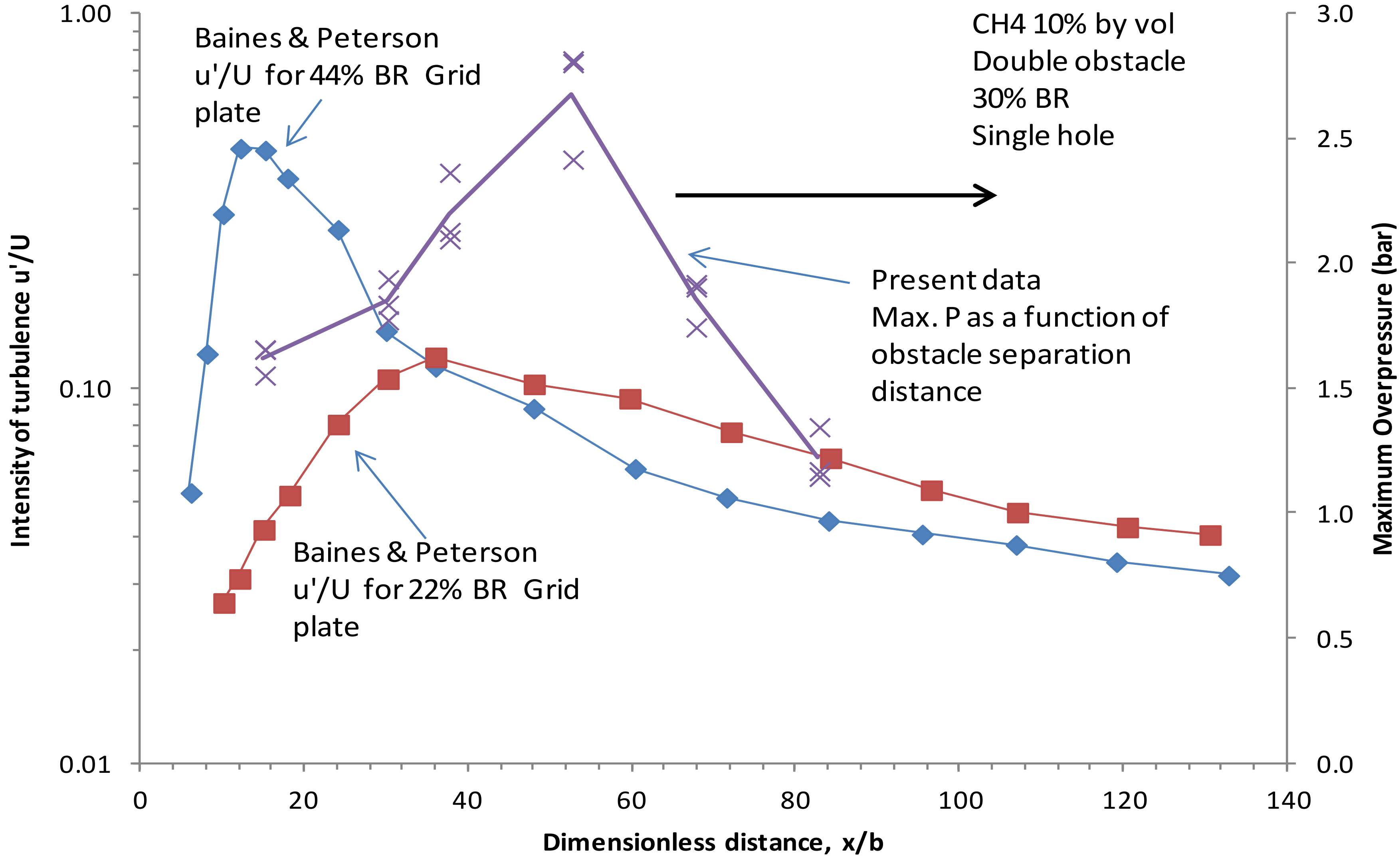
Pressure development with separation distance



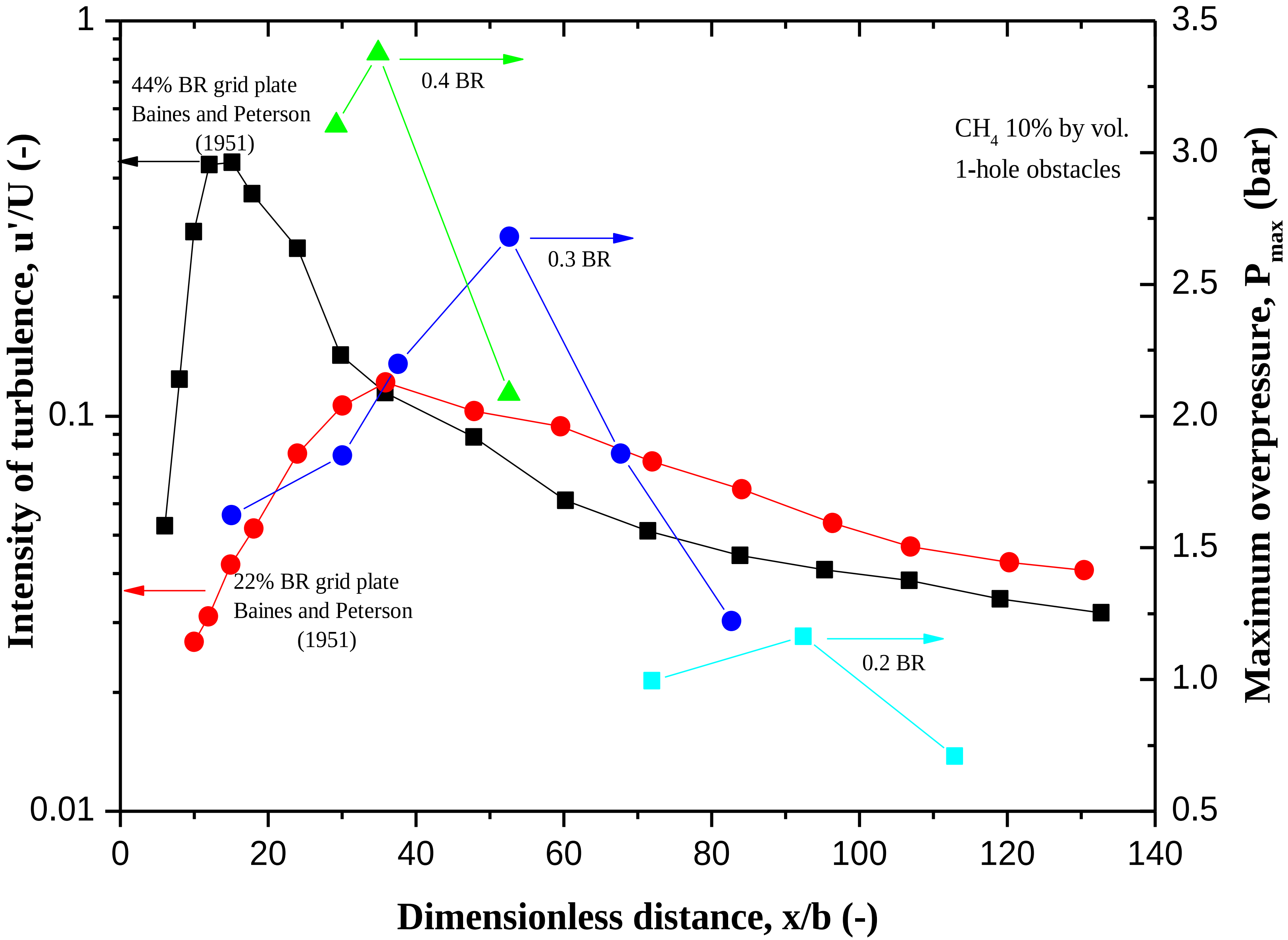
Maximum overpressure and flame speed as a function of dimensionless separation distance



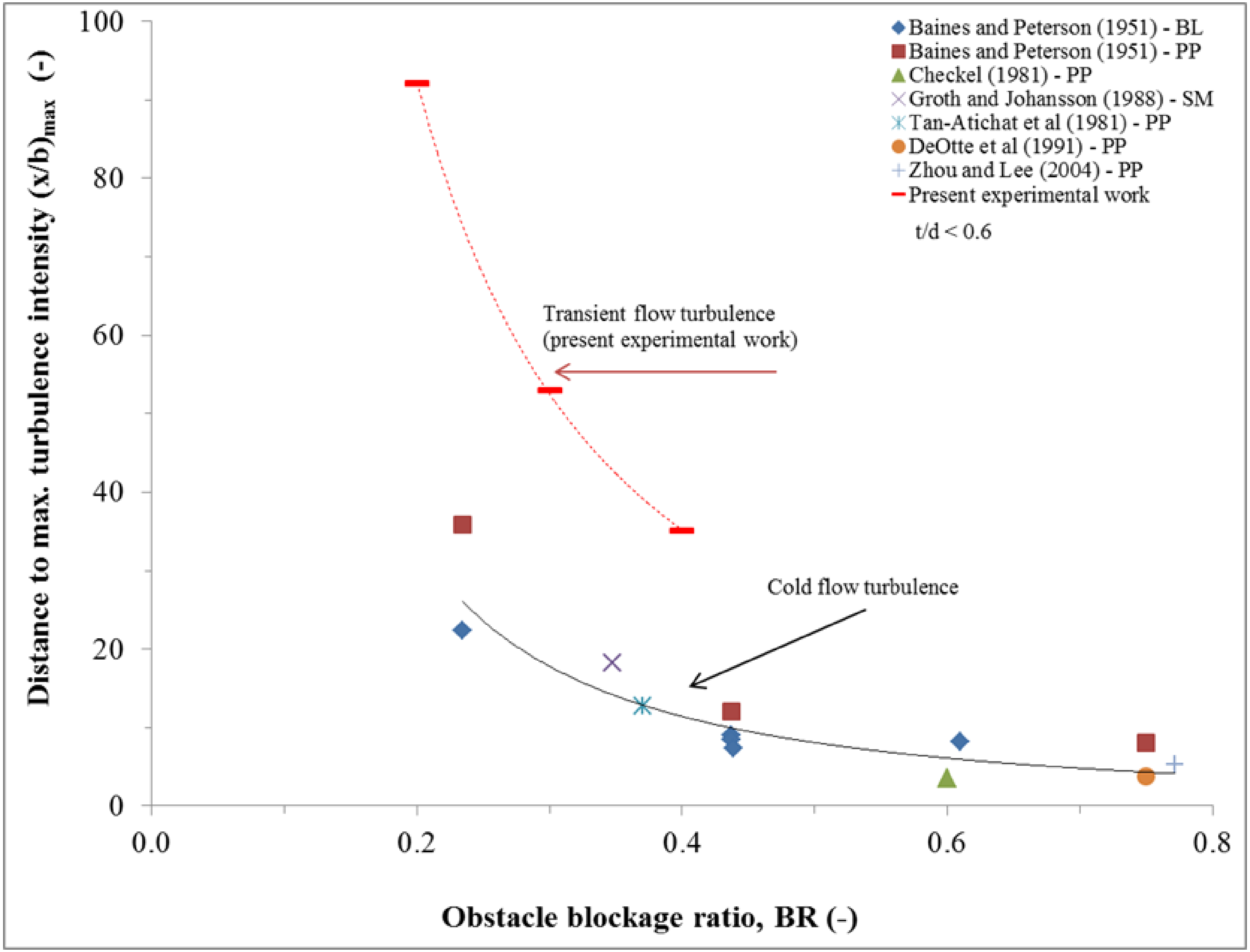
Comparison with Cold Flow Turbulence

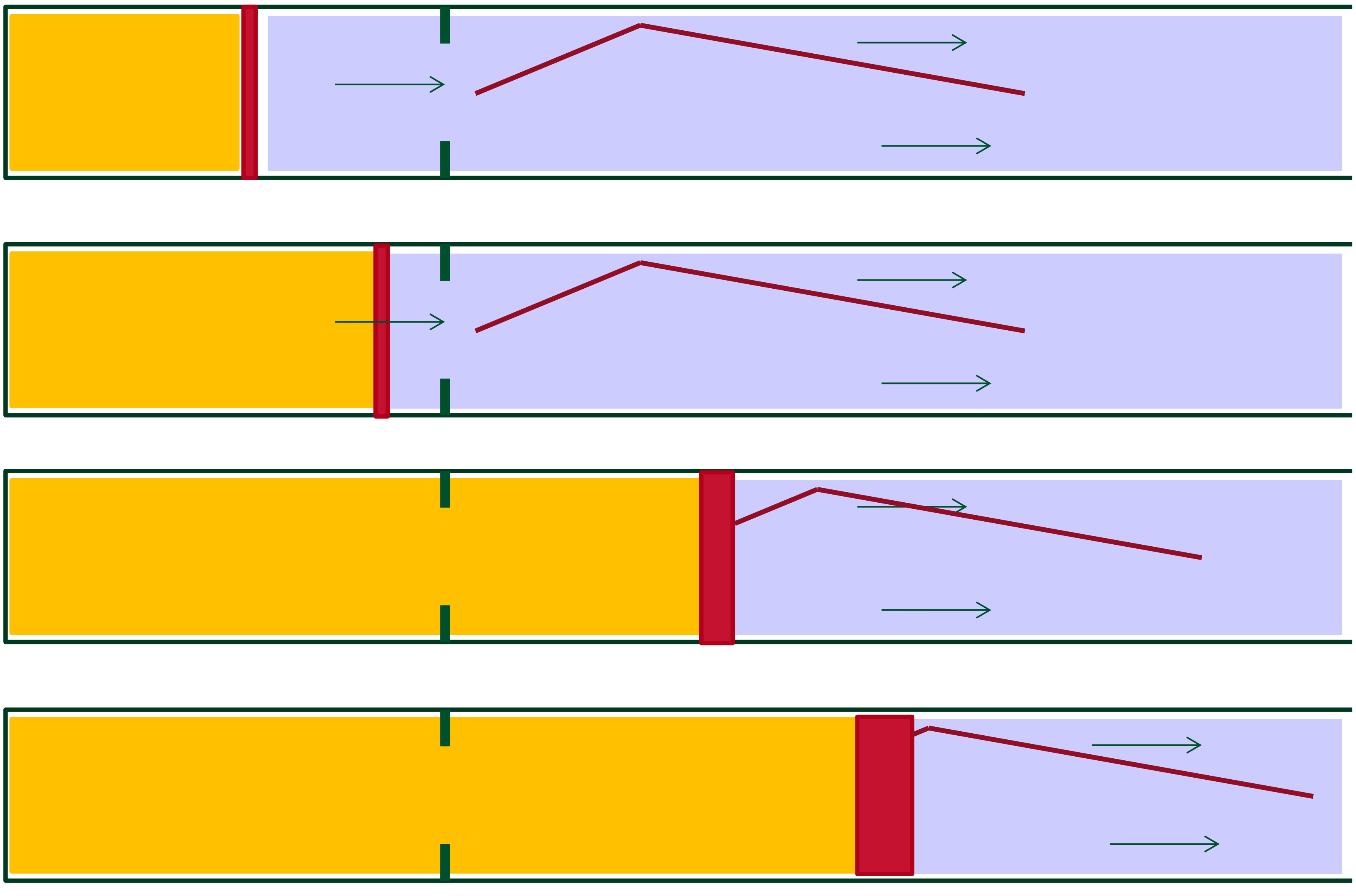


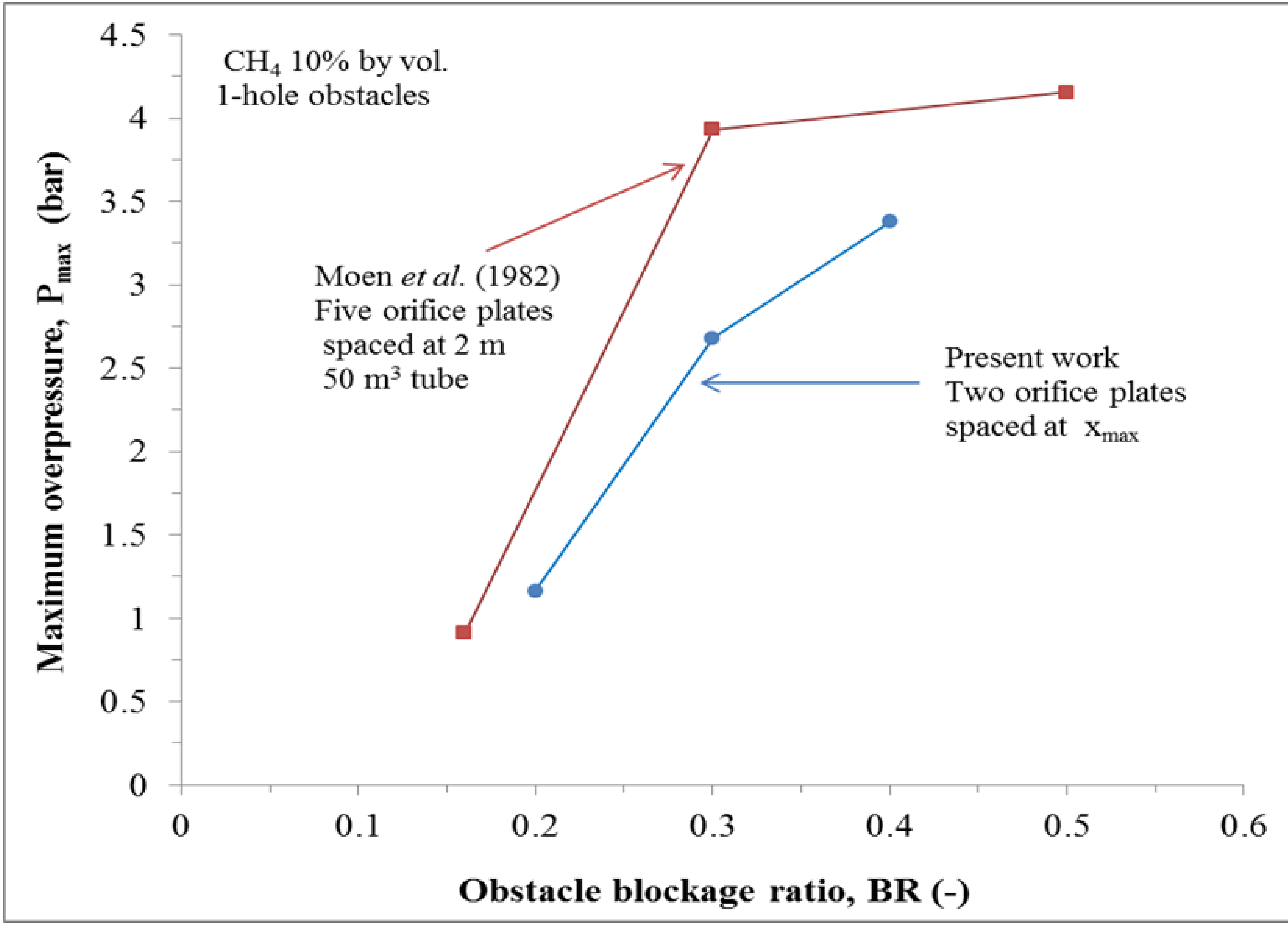
Effect of blockage ratio



Optimum separation distance compared to position of maximum cold flow turbulence

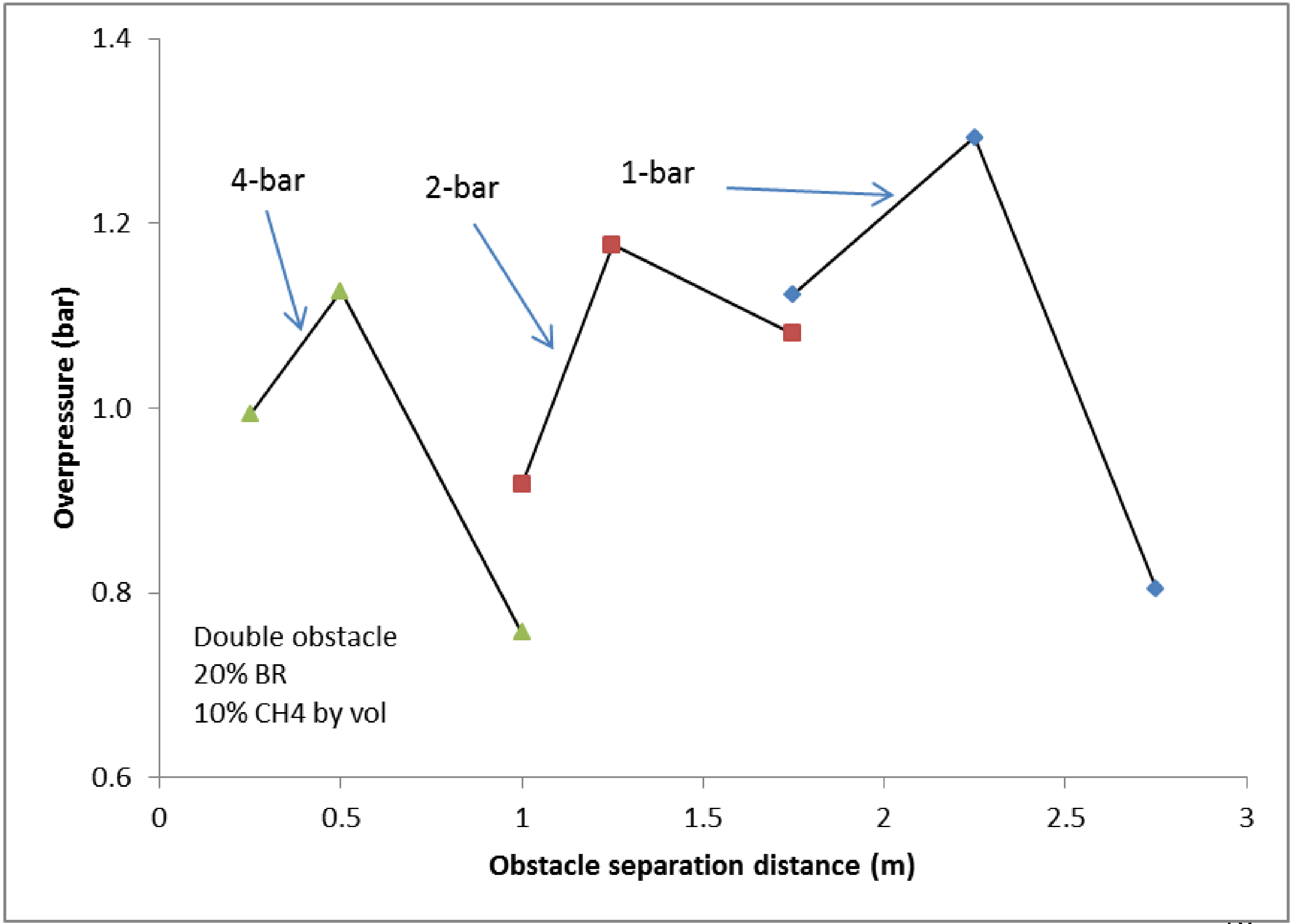


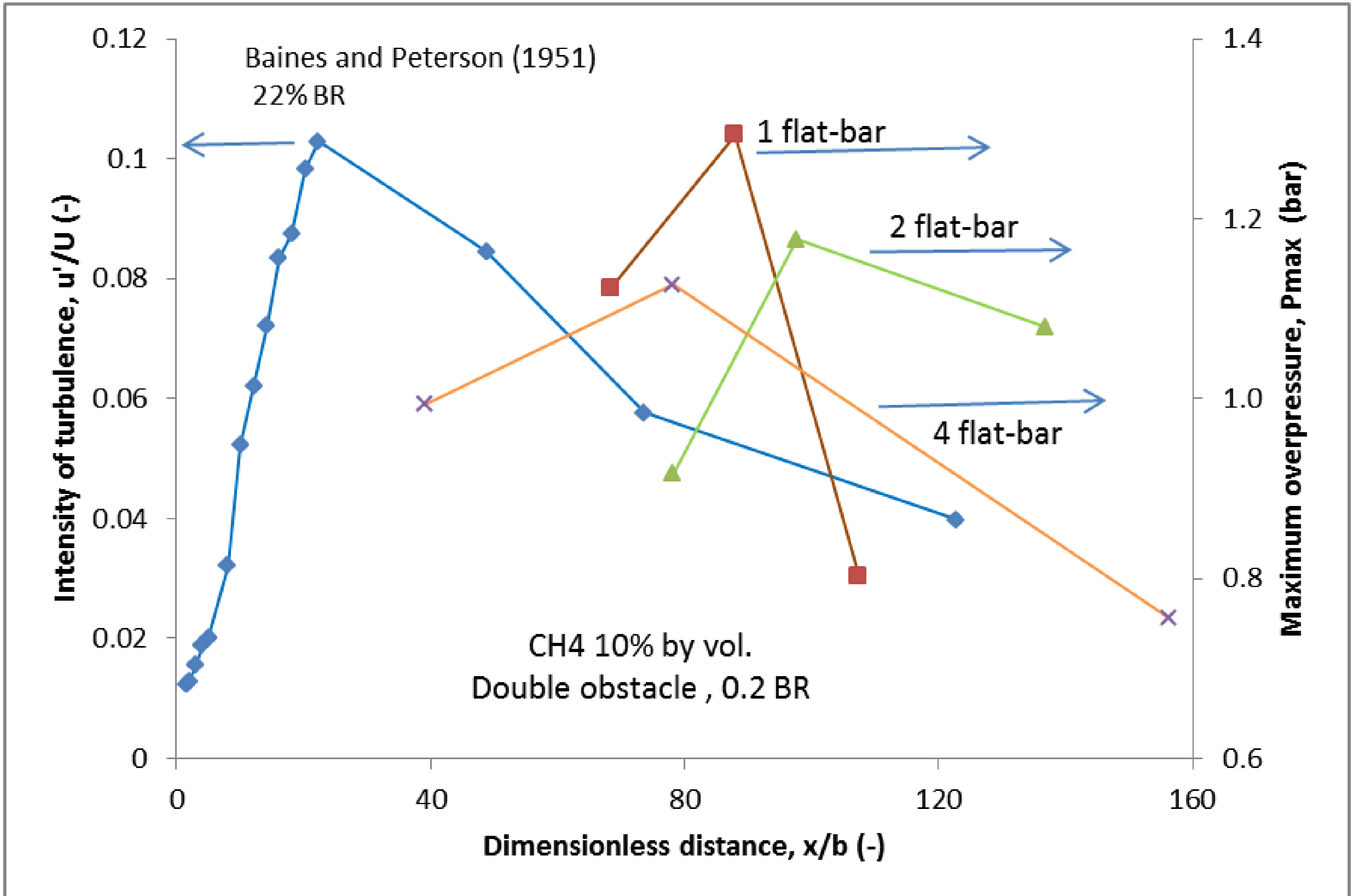




CH4 10% by vol.
1-hole obstacles
Moen et al. (1982)
Five orifice plates
spaced at 2 m
50 m³ tube
Present work
Two orifice plates
spaced at xmax
Maximum overpressure, Pmax (bar)
Obstacle blockage ratio, BR (-)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
0.1
0.2
0.3
0.4
0.5
0.6

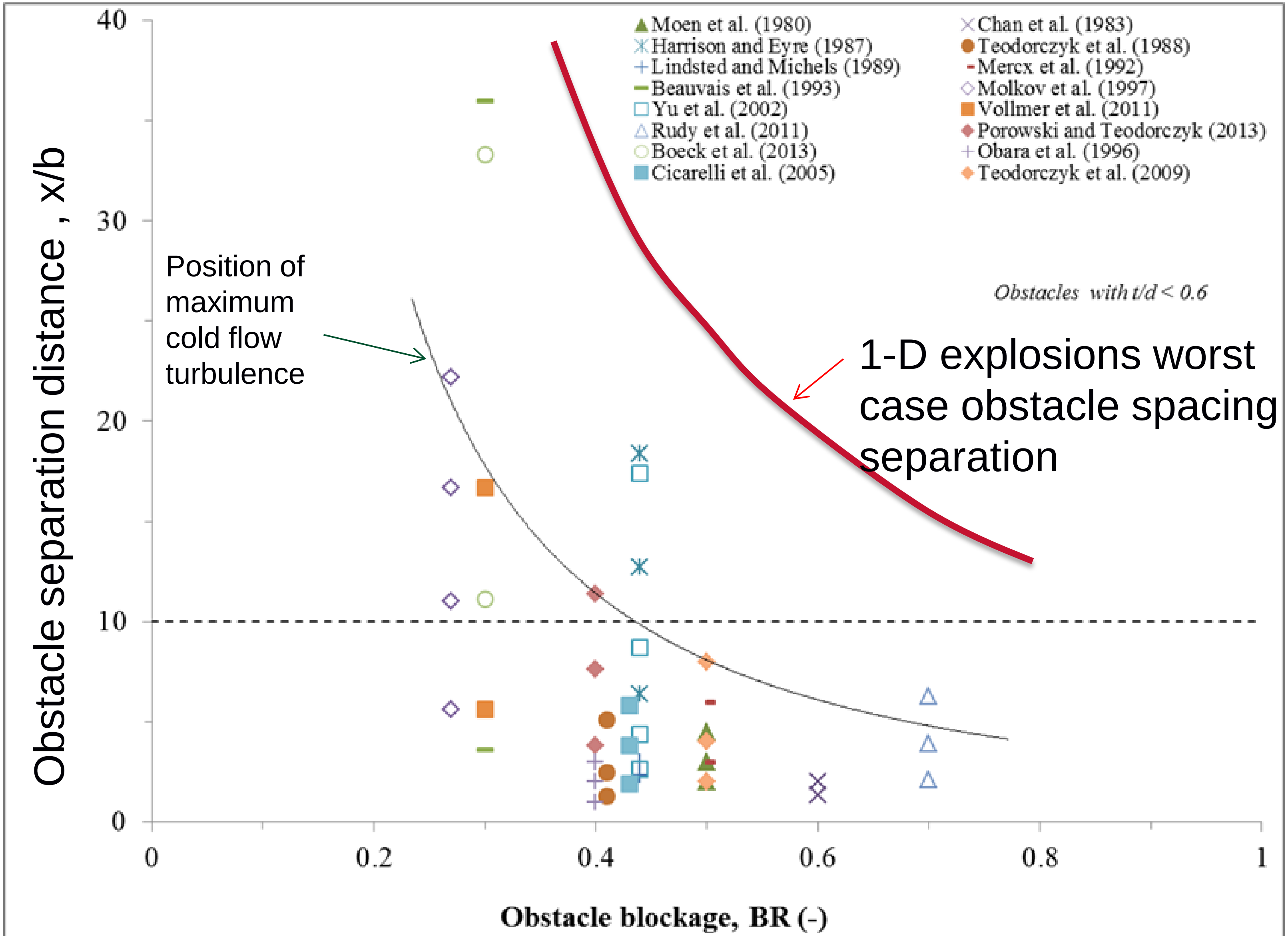
Effect of obstacle scale, (flat-bars)



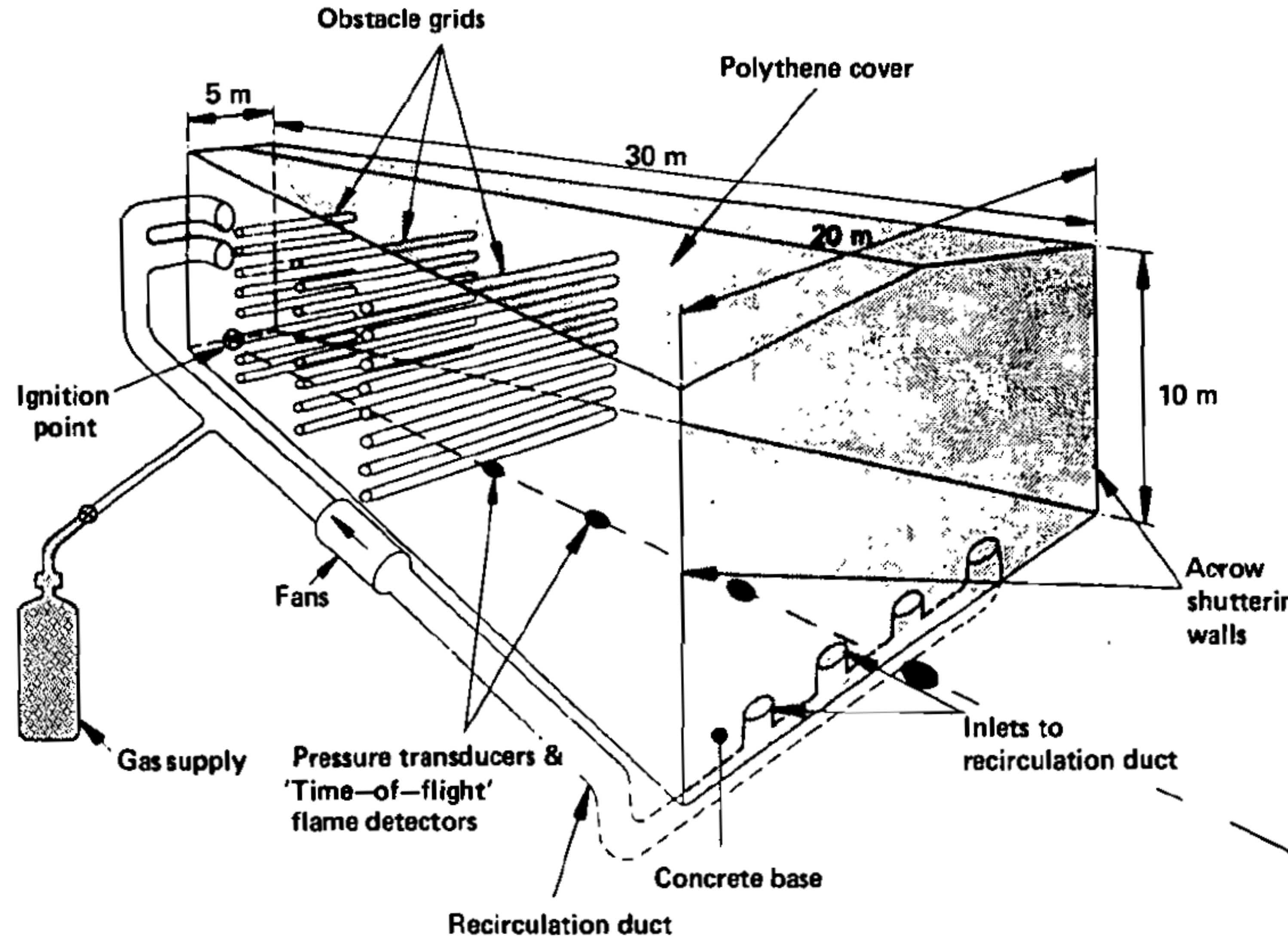


0.12
0.1
0.08
0.06
0.04
0.02
0
Intensity of turbulence, u'/U (-)
Baines and Peterson (1951)
22% BR
1 flat-bar
2 flat-bar
4 flat-bar
CH4 10% by vol.
Double obstacle , 0.2 BR
1.4
1.2
1.0
0.8
0.6
Maximum overpressure, Pmax (bar)
0
40
80
120
160
Dimensionless distance, x/b (-)

Explosion & Detonation studies with variable obstacle spacing



Harrison & Eyre (1987)

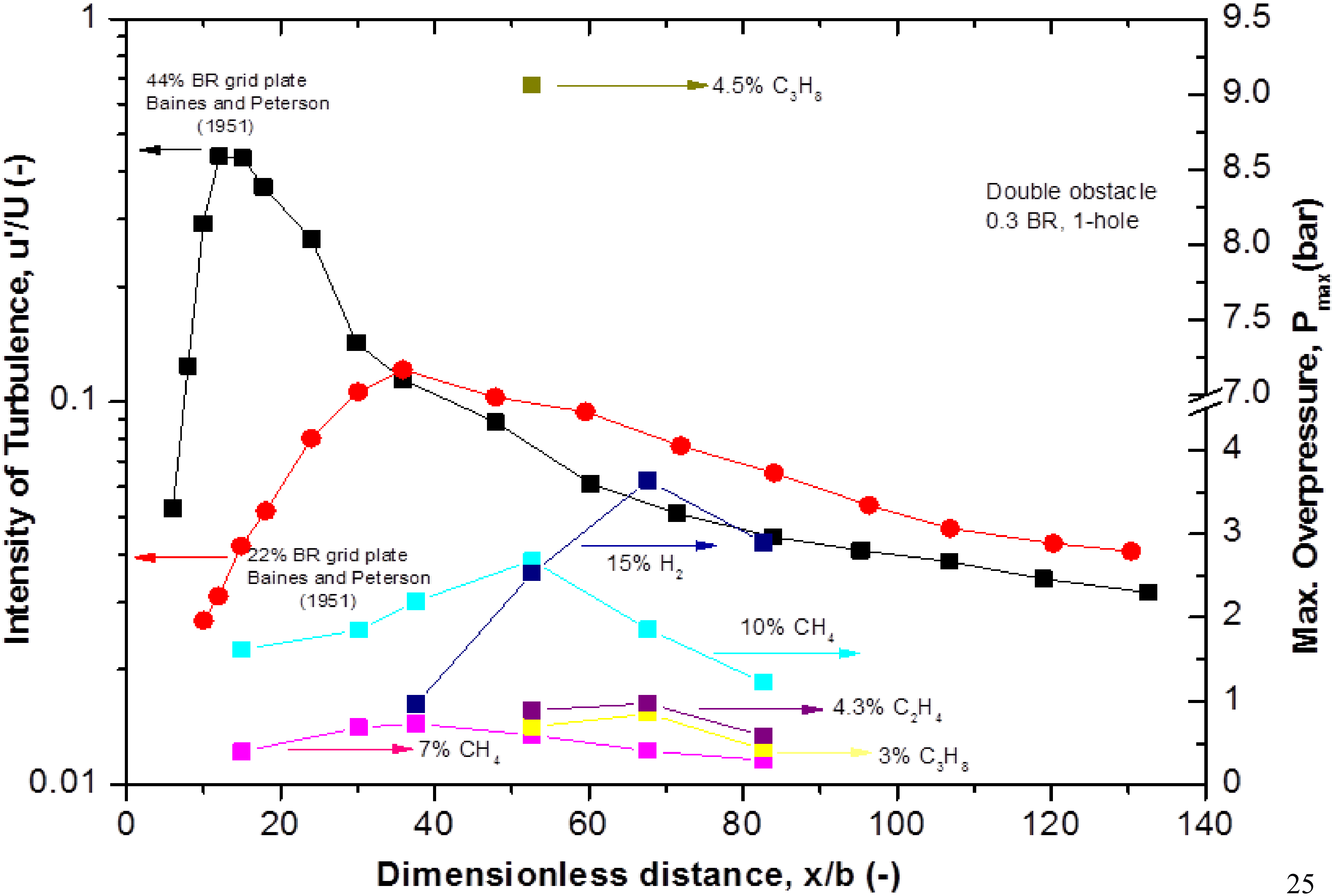


Conclusions

Importance of the obstacle separation distance in a simple double obstacle configuration clearly demonstrated.

- Profile of influence of separation distance consistent with cold flow turbulence profile
    - Position of maximum effect shifted further downstream in the explosion tests aproximately by a factor of 3. This may be dependent on freedom of expansion directions
- Characteristic obstacle scale shown to be an appropriate scaling parameter.
- In practical applications the worst case separation distance needs to be avoided and in designing suitable experiments the worst case has to be incorporated.
- The results would suggest that in many previous studies of repeated obstacles the separation distance investigated may not have included the worst case set up, and therefore existing explosion protection guidelines may not account for worst case scenarios.
- Findings also have application in the critical separation distance between congested areas.

Fuel type	**Conc.(v/v)**	**Ø**	**S_L**	**E**	**Le**	**Ma**
(-)	(%)	(-)	(m/s)	(-)	(-)	(-)
CH_4	10	1.06	0.45	7.49	1.0	3.5
CH_4	7	0.72	0.24	6.26	1.0	-0.2
C_3H_8	4.5	1.12	0.53	8.10	0.8	2.6
C_3H_8	3	0.74	0.25	6.37	1.8	6.0
C_2H_4	4.3	0.65	0.30	5.82	1.3	3.0
H_2	18	0.52	0.97	5.09	0.5	-0.8
H_2	15	0.42	0.41	4.65	0.7	-1.2



44% BR grid plate
Baines and Peterson
(1951)
4.5% C_3H_8
Double obstacle
0.3 BR, 1-hole
22% BR grid plate
Baines and Peterson
(1951)
15% H_2
10% CH_4
4.3% C_2H_4
7% CH_4
3% C_3H_8
Intensity of Turbulence, u'/U (-)
Max. Overpressure, P_{max} (bar)
Dimensionless distance, x/b (-)